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High-intensity intervals versus continuous endurance for weight loss and fitness enhancement

Review Paper

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Declaration

I hereby declare that this work is my own and that the authors of all relevant research used in this paper were referenced as per APA6 protocol.

Gianluca Barbara

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Contents (Review Paper)

Common Abbreviations

Abbreviation	Term
1RM	One repetition maximum
Acetyl-CoA	Acetyl Coenzyme A
BFP	Body fat percentage
BMI	Body mass index
BP	Blood pressure
CET	Continuous endurance training
COX	Cytochrome c oxidase
CVD	Cardiovascular disease
DBP	Diastolic blood pressure
FMD	Flow mediated dilation
GLUT4	Glucose transporter type IV
HDL	High-density lipoprotein
HIIT	High-intensity interval training
HR	Heart rate
HRmax	Maximum heart rate
LDL	Low-density lipoprotein
MCT1	Monocarboxylate transporter 1
MCT4	Monocarboxylate transporter 2
OGTT	Oral glucose tolerance test
SBP	Systolic blood pressure
TAG	Triacylglyceride
TCA cycle	Kreb's Cycle
TG	Triglyceride
VLDL	Very-low-density lipoprotein
VO_2max/VO_2peak	Maximal oxygen uptake

Abstract

The aim of this paper was to provide a broad review of the already established evidence detailing the efficacy of **high-intensity interval training (HIIT)** in weight loss, body compositions and fitness. In doing so, a clearer picture would be formed on the importance of HIIT in health, longevity and the reduction of chronic disease. A comparison was made with continuous endurance exercise (CET) which is an already established form of exercise in the regard of the stipulated outcomes.

A search was conducted using specific keywords and using the databases **Google**, **EBSCO**, **SPORTDiscus**, **MEDLINE** and the **University of Chester portal**, which gave access to supplementary articles which were deemed important for this research.

A **literature review** was then conducted whereby established evidence of HIIT was highlighted in the form of a review (Section 3) and **rationale for the research project** was given in relation to the formulation of the chosen research question (Section 4).

1 - Introduction

1.1 What is high-intensity interval training?

HIIT is exercise that incorporates high-intensity short duration protocols, coupled with a short recovery period which is usually active in nature (Feito, 2014). The “high intensity” nature of this training is an often holistic term as the exercise output will vary between individuals. However, physiological parameters such as VO_2peak or HR_{max} can be used to ascertain the definition of “high intensity”. The high-intensity/low-intensity ratio (for example; 30 seconds heavy, 60 seconds light) is variable, and is affected by factors such as **level of fitness**. The overall length of training is usually shorter than that that of continuous endurance training (CET). This was the principal rational used to undertake the study as Smith (2008, p.1) notes that a “lack of time” is among the most common reasons why people do not undertake physical activity. Thus, HIIT may be a considered an alternative to CET in the reduction of weight and health maintenance. It can be used in conjunction with aerobic equipment such as cycles or treadmills, weights or using one’s own bodyweight (Feito, 2014). One example, the Wingate protocol makes use of supramaximal exercise via cycling (Bar-Or, Dotan and Inbar, 1977). It can also use supramaximal exercise, which involves intensities greater than 100% of the VO_2peak. HIIT was thus the chosen intervention in this study and was given critical appraisal in conjunction with studies in conjunction with CET.

1.2 What is continuous endurance training (CET)?

CET refers to prolonged, uninterrupted activity (for example rowing, swimming or running) which is of a submaximal intensity (< VO_2peak). The training will go on for a variable, author-specific time frame (for example, over 30 minutes). Exercise recommendations are usually centred on this form of physical activity (WHO, 2010) due to the host of available evidence detailing its success. Therefore, CET was used as the "comparison" component of this study. Zuhl and Kravitz (2012) highlight 4 common CET protocols:

- **Maximal-Lactate Steady-State (MLSS)**; the highest workload maintained over a specified time period (20-50 minutes)
- **Alternating-Aerobic-Modes Endurance**; the alternation of aerobic modes (example, treadmill and elliptical trainer) every 20-40 minutes of aerobic exercise (intensity must remain at 70% HR_{max} or greater)
- **Stepwise Endurance**; the steady progression from 50% HR_{max} to 60% HR_{max} to 70% HR_{max} (10 minutes each)
- **Mixed-Pace Endurance**; a variably-timed workout routine with randomly mixed paces

1.3 HIIT (intervention) in comparison to CET (comparison)

The WHO (2010) stipulates that 30 minutes of CET (moderate-intensity brisk walking) is essential to decrease chances of all-cause mortality, CVD, diabetes, metabolic syndrome and cancer. However, a lack of available time may prevent individuals from partaking in most forms of physical activity. Thus, it may be more worthwile to utilize HIIT, which can be of lower frequency and duration in comparison with CET. This paper aims to use the PICO (population, intervention, comparison, outcome) principle (Bragge, 2010) to compare the efficacy of HIIT with CET, and in doing so, determine whether a substitution of CET with HIIT would be ideal to any individual.

2 – The Search

2.1 Journals and databases used

The first search engine used was that of **Google** (www.google.com) due to the fact that it provided a vast amount of information from non-peer reviewed web articles and web sites among other journals. This was important as it yielded good resources for general views as well as old and new research relating to the field of study. **Google Scholar** was also used as a means to locate published articles. Since the topic was primarily an exercise related issue, **EBSCO** was utilised (www.ebsco.com). This is due to the fact that **EBSCOhost** was the only platform for **CINAHL** and **SPORTDiscus** databases. SPORTDiscus was of critical importance when searching the evidence in practice, as most studies were found from this database. Others used for the purpose of this study were **Pubmed** (www.ncbi.nlm.nih.gov) which provided many results from **MEDLINE**, which were more of a generic nature.

Using the library tab on the **University of Chester portal** (https://portal.chester.ac.uk), it was possible to gain access to articles which required a specific subscription or online access to view. This was frequently done via an **OpenAthens alternative login** using student details of the University of Chester.

2.2 Keywords

The literature search for the review was conducted in two phases. Searches were issued to locate information on:

1. HIIT and CET as appropriate modes of exercise, often in comparison with a control.

2. HIIT in comparison with CET as the more efficacious exercise.

Thus, search strategies were conducted using the PICO principle as it considered an intervention, comparison and outcomes which were essential to determine the efficacy of HIIT (intervention). For the purpose of obtaining a holistic understanding of the intervention, all humans were used as the chosen population during the initial review. However, a project report was conducted using a population of adults aged 18-69. Younger (<18 years) humans were excluded in order to target individuals outside of a standardised scholastic regime and older (>69 years) due to diminished bone strength, which may have confounded the data. The keywords shown in Table 1 were used.

Table R.1: *The PICO keyword structure*

Population	Intervention	Comparison	Outcome
Adult*	High-intensity	Endurance	Fitness
	Inter*	Run* or Jog*	Composition
	HIIT	Cycl*	Weight
	Interval training	Submaximal	BMI

3 – Literature Review

3.1 The evidence in relation to HIIT

Since CET has shown its efficacy in the reduction of human rates of morbidity and mortality (Smith, 2008), the World Health Organization (WHO, 2010) proposed guidelines whereby a minimum of 30 minutes of prolonged moderate intensity exercise (i.e. CET) are needed to decrease chances of all-cause mortality, CVD, diabetes, metabolic syndrome, cancer and depression (WHO, 2010). This daily exercise can also minimize the risk of hip/vertebra fractures, promote cardiorespiratory and muscular fitness and achieve a healthier body mass and composition (WHO, 2010).

6 weeks of 6-7 bouts of 20 second high-intensity intervals (170% VO_2max) and 10 seconds of light activity was shown to increase maximal oxygen uptake by 13% in nine college students (Tabata et al., 1997). Since there was no statistical difference between that and 6 weeks of 4-5 bouts of 30 second high-intensity intervals (200% VO_2max) with 2 minutes light activity, it was perceived that high oxygen uptake for short bursts may lead to significant stress on the aerobic system, resulting in an increase in maximal oxygen uptake (Tabata et al., 1997). 10 weeks of HIIT conducted at 80-90% HR_{max} had also caused a significant decrease in insulin resistance, serum chemerin levels as well as body mass index (BMI) and body fat percentage with $p < 0.05$ (Riyahi-Malayeri, Nikbakht and AliGaeini, 2014, Kordi, Choopani, Hematinafar and Choopani, 2012). The investigation of chemerin levels was of importance as high chemerin levels have often been correlated with the development of type 2 diabetes. Conversely, resting adiponectin levels post-intervention in a HIIT group were also statistically larger (Perry, Heigenhauser,

Bonen and Spriet, 2008) with $p = 0.047$. This was considered important in relation to this study due to its function to regulate glucose and fat oxidation. Another study showed that two weeks (7 sessions) of HIIT was enough to increase fat oxidation by 36% (Talanian et al., 2006) as well as VO2 peak (13%), whilst having no significant effect on muscle glycogen and triacylglycerides (TAG). In fact, Perry et al. (2008) showed an increase in muscle glycogen content (59%) as well as an increase in GLUT4, MCT1 and MCT4 concentration by as much as 14-30%. The fact that muscle glycogen was retained, suggests that more fatty acids were being oxidized. This could be the mechanism by which BFP was reduced. In addition, HIIT was shown to enhance aerobic capacity (Ouerghi et al., 2014), muscle power, endurance capacity and aerobic power (Maddigan, Behm and Belfry, 2014). Burgomaster et al. (2005) showed how 2 weeks of sprint interval training, via a Wingate test, (with each bout occurring with 1-2 rest days in between) increased citrate synthase (an enzyme which catalyses the reaction of acetyl-CoA and oxaloacetate to citrate in the TCA cycle) by 38% ($p < 0.05$). The authors also noted a 100% ($p < 0.05$) increase in cycle endurance capacity despite no change in VO_2max. Thus, it was noted that HIIT could potentially be used to achieve weight loss (via increase in TCA cycle activity) as well as performance enhancement.

In diabetic patients, various HIIT regimes showed a statistical difference in resting heart rate, systolic blood pressure (SBP), diastolic blood pressure (DBP) and fasting glucose levels and overall body weight (Parpa, Michaelides and Brown, 2009). This type of training can also improve postprandial hyperglycaemia and may even be used as a means of preventing type 2 diabetes (Little and Francois, 2014). The cardiovascular fitness and health status of patients with established coronary artery disease was deemed to have improved following HIIT (Warburton et al., 2005), with authors showing that HIIT improved anaerobic tolerance to a greater extent than traditional exercise (i.e. CET).

Some studies also elicited clinical benefits of HIIT in younger populations. Morsal et al. (2014) conducted a study (n = 30) comparing HIIT to a control in adolescents. After administering 3 sessions of HIIT per week, the authors noted significant reductions of bodyweight and conversely BMI in the intervention group (after 6 weeks). Prasana Sundara Raju (2014) used 3 sessions per week (n = 24), in comparison to a control, to elicit changes on obese, male school children. Aside from weight loss, aerobic capacity was increased by 7.27% (p = 0.000) after training in an 8 week trial.

3.2 Rationale behind the use of HIIT

The logical use of HIIT stems from our genetic make-up as humans, animals and even more so – predators. So much so, that it was once the case were humans were forced to hunt for prey as a means of survival. This, like most predators, involved stalking, tracking and finally – killing. The latter aspect was characterised by brief moments of supramaximal (>100% VO_2max) activity, coupled with the former lighter activity. The presence of easily acquired food through food stores does not necessitate this kind of activity. Thus, it is frequently omitted, and as a result, contributes to obesogenic risk factors on a public health level.

In an attempt to control or reduce obesity, however, recommendations for exercise are commonly a minimum of 30 minutes of moderate-intensity CET (WHO, 2010). Although this may promote weight loss, the maintenance of submaximal (<100% VO_2peak) for continuous periods of usually between 20 – 60 minutes, is technically unneeded in humans (from an evolutionary point of view). In light of this HIIT can simulate activity levels humans were specifically designed to perform (Smith, 2008), making use of required energy pathways within the body.

Although HIIT may sound daunting for some, “high-intensity” in itself, is not an objective statement. In essence, what may induce a high-intensity effort for some, may induce a moderate-intensity effort for others. Thus, using a basic and holistic understanding of markers fitness markers such as VO_2max or HR_{max}, one can be more self-aware of how far the body is being pushed. Even so, Albert et al. (2000) stated that the risk of sudden death from high-intensity exercise is lower than 1 per 1.5 million people.

It is important to note that the body adapts to stress (Smith, 2008, p.12), which is why regular maintenance of this form of exercise is crucial in order to continually build upon the current fitness level of an individual by use of HIIT.

3.3 Common types of HIIT

HIIT can be of a diverse nature. The versatile nature of this type of training is a quality, in itself, which can have implications on fitness enhancement. Among several commercial forms such as Insanity®, P90X® and Crossfit® (Feito, 2014), one may find several varying protocols for HIIT existing within the literature. The earliest example of such, is the Wingate protocol, which involves 30 seconds of cycling at 90% VO_2max coupled with 240 seconds of recovery activity, repeated for 4-6 times (Bar-Or et al., 1977). This adds up to 2-3 minutes of exercise at a high intensity level and 15-25 minutes of low intensity exercise per session.

Other forms of HIIT may use running, cycling or bodyweight training (such as plyometrics) in a specific ratio of high-intensity to low-intensity. The most frequent of which are:

- high-intensity 2:1 low-intensity (for example, 60 seconds: 30 seconds)

- high-intensity 1:2 low-intensity (for example, 30 seconds: 60 seconds)
- high-intensity 1:1 low-intensity (for example, 30 seconds: 30 seconds)

3.4 Comparable outcomes of HIIT and CET

Zuhl and Kravitz (2012) state that during cardio-exercise, performance is dependent on heart rate, stroke volume (amount of blood pumped per beat) and heart contractility (heart contraction force). These variables are important as ultimately, they influence the oxygen supply (vis-à-vis the blood flow) given to the exercising muscles.

This paper attempts to compare HIIT directly with CET in order to determine the more beneficial exercise in terms of body compositions, fat oxidation and fitness enhancement. A trial on 9 males by Skelly et al. (2014) attempted to show a comparison of 1 session of HIIT versus CET and found that:

- CET group (total energy expenditure: 547 ± 56 kcal)
- HIIT group (total energy expenditure: 352 ± 34 kcal)

Despite the reduced total energy expenditure (TEE) in the HIIT group, total VO_2 estimated over 24 hours were both greater than those of the control group ($p < 0.05$) and not statistically different from each other. There was no significant difference in the respiratory exchange ratio (RER) at any point.

This study aimed to investigate the efficacy of HIIT in comparison to CET in the achievement of a leaner body composition. This is due to the fact that although adults may be within a normal BMI range, they may still have higher body fat percentages and a reduced fat free mass. This is important as it allows attention to be drawn particularly to fat oxidation. Kilani and Abu-Eisheh (2009) an ideal body composition would be related to actual lean body mass symmetry combined with a low body fat percentage (around 5-6%-6.7% in men) as this has positive implications on improved longevity. Ridgeway and Tylka (2005) stated that after surveying individuals, people already thought that being lean was the most important component of body image.

Body composition is rarely measured in literature which has led to an incomplete understanding of how the influence of BMI on body image may differ from that of fat mass (FM) and fat free mass (FFM), (Streeter, Milhausen and Buchholz, 2012). VO_2peak was markedly increased in 8 sedentary and recreationally active individuals (+44%, $p < 0.05$) after 10 weeks of HIIT. In 4 individuals, VO_2max exceeded 60ml/kg/min (Hickson, Bomze and Holloszy, 1977)

3.5 The importance of Intervals

When 10 overweight men were subject to either HIIT or moderate-intensity interval training (MIIT). They had both shown significant ($p < 0.01$, in both) increases in fat oxidation (Alkahtani, King, Hills and Byrne, 2013). Astorino et al., (2013) had performed a similar study using 23 sedentary women in order to determine whether the presence of intervals in training is a contributing factor independent of high intensity or moderate intensity (MIIT) activity. This was done by comparing two groups:

- HIIT group (3x per week for 12 weeks) used 6-10 bouts of 60 seconds at 80-90% VO_2peak
- MIIT group (3x per week for 12 weeks) used 6-10 bouts of 60 seconds at 60-80% VO_2peak

The HIIT program (shown above) improved maximal fat oxidation ($p = 0.05$, 19%-25%) and minimum fat oxidation ($p = 0.001$, 22-24W). However, the magnitude of improvement was similar between HIIT and MIIT ($p > 0.05$), even though no change in bodyweight was noted (Astorino et al., 2013).

4 – Rationale for further Research

4.1 The Aims of the Study

The purpose of this study was to compare the efficacy of HIIT on weight loss, leaner body compositions and fitness. The existing evidence in relation to HIIT suggests that it may be another option for individuals who are unable to perform CET.

4.2 Rationale for the chosen study approach

A systematic review was determined to be the best approach for this study for several reasons. Firstly, studies investigating specific exercises tend to have a low sample population. By use of systematic review, one can correlate between studies based on similar inclusion/exclusion criteria and be able to draw conclusions with respect to the population under representation. Secondly, the investigation of one form or exercise with another could potentially render a study as biased. Thus, the analysis of several biochemical markers (for example, citrate synthase, pyruvate dehydrogenase…), physical markers of exercise (*VO_2max, HRmax*…) and different populations (males, females, obese, overweight) could provide a more holistic approach to the determination of whether HIIT is more beneficial than CET. Lastly, the investigation of the efficacy of HIIT versus CET in its totality requires more than the analysis of a single study, but rather, all studies within a certain inclusion/exclusion criteria.

The Downs and Black Model (Downs and Black, 1998) was used to assess the quality of the studies chosen for this paper. This is due to the fact that the Downs and Black model caters for various study designs and does not omit studies which do not have blinding (which would be difficult for studies involving exercise).

The study outcome focussed on the achievement of a leaner body composition. However, as a means to further analyse the chosen outcome, several other co-outcomes were considered:

- **Bodyweight (or BMI) reduction**; as the action of "becoming leaner" commonly incorporates the reduction of weight via fat oxidation if not the increase in lean body mass.
- **Fat oxidation and changes in body fat percentage (BFP)**; as the action of "oxidizing fat" can be a contributing factor towards the achievement of a lean body mass. Thus, the BFP is a factor which requires measurement.
- **Fitness enhancement**; this was deemed important as the increase in fitness will mean a greater stress during exercise while still under the same effort. Thus, the effects of training could be enhanced independent of exercise. This meant that changes in VO_2peak, RER, lactate threshold, inflammatory markers (CRP), 1-Rep (1RM), bio-enzyme markers and other entities deemed important were followed up in the results.
- **Adherence to Exercise**; this was considered as an injury or lack of enjoyment in a particular activity may lead to the cessation of it. Thus, it would hinder a subject from attaining changes in the above three factors. The fact that HIIT is usually conducted in a shorter time-span (and with greater variability) could have been an important factor for adherence.

4.3 The research question

The findings of this study were used to determine the following points:

- In an adult population, is HIIT more effective than CET in the achievement of **weight (or BMI) reduction**?

- In an adult population, is HIIT more effective than CET in the achievement of a **leaner body composition**?
- In an adult population, is HIIT more effective than CET in **fitness enhancement**?
- Are adults more **prone to adhere** to HIIT as opposed to CET in terms of **enjoyment or injury**?

With these concepts in mind, a research question was formed using the PICO (population, intervention, comparison, and outcome) principle (Bragge, 2010). This allowed a more direct question to be asked and also allowed for a more objective approach to searching the evidence in section 4.1. Thus, the research question was: **"Is HIIT more beneficial than continuous, low to moderate-intensity cardiovascular activity for the improvement of fitness?"**

4.4 An adult population in relation to the research question

Adults where used in this study with the idea of targeting individuals with a more diverse background. Adults in common occupational settings are usually physically limited and for large periods of time. As a result, this study was to involve literature which used subjects who were sedentary, overweight, obese, athletic (recreational or advanced) or even individuals with chronic disease (if stipulated by the individual study). The participants could have also been males or females. Population criteria was further specified in the search strategy (Section 4.1).

4.5 Assessing the quality for each article using the Downs and Black (2008) model

The Downs and Black (1998) model was used for quality assessment in this study. This model utilises a 27-question checklist approach and was regarded as highly useful for many studies which are not limited to randomized controlled trials. This was important as for a study investigating two different forms of exercise, it would be practically impossible to utilise double-blinding. This being said, there might always be some form of bias present within the results.

When investigated for its efficacy as a quality assessment tool, Downs and Black (1998) investigated face and content validity, assessed by three experienced reviewers assessing 10 randomized and 10 non-randomized studies. The results yielded a high internal consistency of the Quality Index (KR-20: 0.89) for both randomized and non-randomized studies.

The application of the inclusion/exclusion criteria resulted in the triangulation of six articles, which were deemed most relevant to investigate the proposed research question. Thus, a quality assessment was performed in order to fully determine the quality of each article using the Downs and Black (1998) model.

The first 10 questions dealt with reporting. In questions 1-5, a score of 1 was given where the answer was “yes” and a score of 0 was given when the answer was “no”. In questions 6-10, a score of 2 was given where the answer was “yes”, a score of 1 was given when the answer was “partially” and a score of 0 was given when the answer was “no”. Questions 11-26 had scored a 1 for a “yes” or a 0 for a “no” or “unable to determine” or “UTD”. Finally, question 27, could have had a quality score anywhere between 0-6, depending on the overall strength of the study.

4.6 Standardisation of findings within the review

Due to the fact that studies incorporated in the review utilised varied approaches in the determination of their findings, it would have been highly beneficial to formulate an objective approach in analysing the data. This was important as each study had used different approaches in order to find different results. Thus, to avoid having a base of findings which could be considered too vast in comparison to the scope of the study, the author's studies were compared using the following criteria:

1. **Publication Year** – this parameter was important as it emphasises consideration that the more recent studies may have had facilities which were more equipped to deal with the issue, particularly that of a fitness one.
2. **Participants Number** – the greater the number, the better in terms of statistical strength.
3. **Population Type** – this could have been any untrained individual (sedentary, lightly active, overweight, obese) and could have implications on the findings of the study
4. **Intervention training** – variations in the ratio, duration and VO_2peak of the study, may hinder or enhance the effect the intervention has on weight loss and fitness enhancement
5. **Intervention frequency** – this constitutes how often in 1 week was HIIT performed and for how many weeks. Logically, this may also have implications on the totality of effect HIIT may have on an individual
6. **Comparison training** – this involves the duration and VO_2peak maintenance during that exercise time.
7. **Comparison frequency** – this details for low long CET was performed as it could have been performed for a longer/shorter period than the intervention trial.
8. **Measurement tools** – this refers to the method by which body composition or physiological data were recorded. This could have ranged from biopsies to calipers to BMI recordings

9. **Findings** – the findings aspect of the data analysis referred to any change which was deemed statistically significant (i.e. $p < 0.05$)

5 - Conclusion

The presenting literature within this review gives rise to speculation that HIIT may indeed be just as efficacious as CET in the achievement of weight loss, leaner body compositions and enhanced fitness. The key issues stem from the fact that within a reduced time frame, HIIT could potentially instil a greater sense of work. The presence of intervals, then, would allow for longer periods of sustained high-intensity activity. However, since research regarding this comparison is limited, a systematic review was deemed the favourable option so as to compile existing literature based on similar experimental characteristics. By use of a systematic review, a compilation of available literature may be done and the already established efficacy of CET can be challenged by the limited research available comparing CET directly with HIIT for any of the reasons highlighted in section 3.3. Within this study, the PICO protocol would serve as a means to objectify the collected data in a manner which would allow a thorough comparison of the results formulated within the chosen literature. Within the study there was an additional risk of bias due to the lack of 'blinding' within the data. This proved challenging as it was difficult to blind one form of exercise from another. That being said, cross-over trials would have also proved difficult due to the possibility of a threshold that could have been reached via the first intervention. Therefore, some element of bias would have been present.

Future research would be orientated around trials conducted on different populations such as obese and non-obese, children, adolescents and adults. It would also be beneficial to conduct trials relating on the efficacy of HIIT in populations having already established metabolic syndrome to determine the efficacy of HIIT in the reduction of abdominal obesity, glucose insensitivity and other factors which may contribute to increased morbidity and mortality. Ideally, the presence of differences within the study population may enhance the effect of the comparison between HIIT and CET in the sense that it could provide a more holistic picture of their individual efficacy. This is so because the effect HIIT may have on obese adults may not be carried out in the same proportion were the same training to be used on recreational or advanced athletes. However, this may indicate the presence of a threshold effect that may be brought about through varying levels of already established fitness.

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High-intensity intervals versus continuous endurance for weight loss and fitness enhancement

Project Report

Gianluca Barbara

Intended Publication

This project report is intended for publishing within the **Journal of Sports Sciences**. The reason for this was centred on the fact that this journal, which is housed within the United Kingdom has been consistent in the production of high quality studies dealing with sports issues among other things. The research within this project report deals solely with an exercise issue. However, the information presented through the findings are key components in future recommendations for exercise in terms of weight loss, fitness, and achievement of leaner body compositions.

Contents (Project Report)

Figures

Tables

Abstract

The **aim** of this study was to investigate the efficacy of high-intensity interval training (HIIT) in the achievement of weight loss, lean body compositions and improved fitness. This was done using continuous endurance training (CET) as a comparison due to the vast amount of literature establishing its effectivity in achieving the desired outcomes. The **methodology** was centred on the PICO (population, intervention, comparison, outcome) principle (Bragge, 2010), an objective means of comparison was made whereby suitable literature was extrapolated from several research databases. Using a set inclusion/exclusion criteria, this yielded 10 studies, whose findings were critically appraised as a means of assessing the efficacy of HIIT in this regard. The **results** provided a clearer picture of both exercises in the context of the chosen outcomes, CET seemed more likely to cause weight loss for any chosen adult subject. However, HIIT was conducted in a shorter time-span and often, with reduced frequency – suggesting that it may be a time-efficient means of reducing weight and achieving a leaner body composition. In terms of fitness enhancement, HIIT was deemed more efficacious due to the fact that it enhanced fat oxidation (as deemed by reduced RER) and hindered glycogenolysis despite increasing overall VO_2peak. The activity of many aerobic and anaerobic enzymes were also enhanced with HIIT in comparison to CET. In **conclusion**, it would probably be best to include both CET and HIIT within any exercise regime for health maintenance, however it may be more beneficial to incorporate a larger ration of HIIT due to the additional fitness and cardiorespiratory benefits.

1 – Introduction

Several bodies of evidence have regarded exercise as an invaluable component of modern living for its role in the enhancement of fitness and weight management, longevity and quality of life. So much so, that the WHO (2015) reported physical inactivity as a global public health problem, noting that in 2008, 31% of adults (15 years and above) were insufficiently active (World Health Organization, 2015). Smith (2008, p. 1) comments that a "lack of time" is reportedly the principal cause of physical inactivity. Global recommendations for exercise are currently stipulated as being a **daily minimum of 30 minutes of prolonged, continuous, moderate-intensity activity** to decrease chances of all-cause mortality, CVD, diabetes, metabolic syndrome and cancer (WHO, 2010).

The introduction of **high-intensity exercise (HIE)** can create an opportunity for any individual to utilize the health benefits offered by exercise, through lower lengths and frequencies of physical activity. The introduction of **intervals** during high-intensity training, may then provide a means of extending periods of time where supramaximal (over 100% VO_2peak) is maintained. Thus, high-intensity interval training (HIIT) may provide an easier means to maintain physical activity needs. However, this would only be the case if HIIT was in fact, just as beneficial, or more, than continuous endurance training (CET).

This paper aims to compare and contrast **high-intensity interval training** (intervention) and **continuous endurance training** (comparison), each defined as:

- HIIT; exercise characterised by brief periods of all-out activity coupled with periods of active recovery (Feito, 2014) in a ratio specified by any particular author (generally 20-30 minutes)

- CET; exercise characterised by longer periods of low to moderate intensity activity which is sustained for a stipulated period of time (generally 40 minutes and above)

2 - Method

2.1 Keywords used to search the evidence

The PICO principle was used to formulate the research question and was a key component in executing a search for the most appropriate literature. With reference to this principle, the key search words were:

- **Population**; adult
- **Intervention**; HIIT
- **Comparison**; CET
- **Outcomes**; weight loss, body composition, fat oxidation, fitness

A **population** of adults of 18-69 years was used. This meant that subjects were overweight, obese, male, female, trained or untrained and was deemed necessary due to the fact in order for HIIT to be efficacious with respect to the chosen outcomes, it should be applicable to most adults independent of background. Individuals with a BMI range of under 25 kgm^2 may also benefit from increased fat oxidation and mitochondria density. Studies with older adults (70+ years) were omitted as diminished bone strength might have cofounded the data. Thus, the terms “human”, “overweight”, “obese”, “BMI”, “male”, “female” or even “college” were used to locate studies with relevant candidates. Thus search strategies made use of such terms as well as terms such as “obe*” (use of a wildcard - *) and “weight” to include terms such as “weight management”, and “weight reduction”.

The **intervention**, being “high-intensity interval training” or “HIIT” had several synonyms. These were “high intensity intermittent training” and “sprint interval training", with "inter" being the common syllable. Thus, a search strategy using "inter*" was done as a means of covering the search on a holistic basis.

Since the **comparison** in question was that of "continuous endurance exercise", or "CET", considerations were given due to the broadness of the term. Thus, several synonyms were searched for. These included "LMICT" or "low-to-moderate intensity cardiovascular training", "prolonged training", "cardio*" and "moderate intensity". Lastly, the **outcomes** were characterised by the following terms: "weight", "weight reduction", "fitness", "performance", "results", and "adherence".

2.2 Databases used for the search

After a preliminary search was conducted with **Google** and **Google Scholar** to assess the densities of studies in the area, the databases **SPORTDiscus**, **MEDLINE**, **EBSCO**, **Cochrane** and **Pubmed** were used to find literature in relation to the study. During the search, the keywords were used in a singular basis for optimized specificity. Later, up to three keywords in each search were utilized in order to increase sensitivity (Wilczynski and Haynes, 2003). The search was intensified by use of Boolean Logic Operators. A summary of the keywords is shown in **Table 2**.

***Table P.1**: Summary of the Keywords Used*

Population	Intervention	Comparison	Outcome
Adult*	Hiit	Cet OR LMICT	Weight loss
Overweight	Inter*	Continuous endurance training	Weight
Obe*	High intensity interval training	Endur*	Fitness
BMI	Interval training	Moderate intensity	Enhanc*
Athle* OR Sedentary	Sprint	Jog OR swim OR walk	Fat* AND oxid*
College			Lean

A primary search was conducted targeting results on "**weight loss**":

1. HIIT AND endur* AND weight
2. Inter* AND endur*
3. HIIT AND adult AND endurance
4. Inter* Training AND over OR obe*
5. Inter* training AND cont* endur*

A search was then conducted in order to target results on "**fitness enhancement**"

1. HIIT AND endur* AND fitness
2. Inter* Training AND endur* AND lean
3. HIIT AND endur* AND fat ox*
4. Inter* Training AND endur* AND fat
5. Inter* Training AND endur* AND body fat

2.3 Inclusion/Exclusion criteria for the search

In order to fully assess the efficacy of HIIT in comparison to CET, inclusion/exclusion criteria had to be applied to all articles collected in the search. This was important as it provided a means of control in a vast search criteria obtained in the preliminary search. The **inclusion criteria** was:

1. Articles needed to be available in **full-text format**
2. Articles needed to be available in the **English language**.
3. Studies must have been performed on individuals between the **age of 18-69 years**
4. HIIT must be **directly correlated** with CET and not only a control, within in a trial
5. The **type and frequency of exercise of both the intervention and comparison are clearly stipulated**.

6. **Subjects with no pre-existing health disorders can only be used, unless stated otherwise**.

Studies were conversely **excluded** if, after satisfying all inclusion criteria, they did not provide results for at least 2 of the 4 stipulated outcomes (weight loss, improved body composition, fat oxidation and fitness enhancement). If a study was not selected, it was still used in brief to support the established evidence.

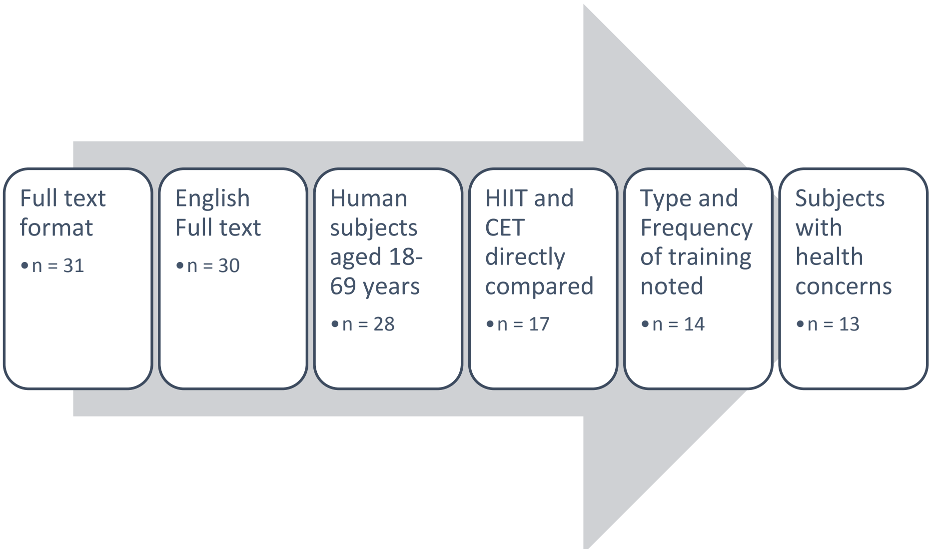

Figure 1: *Flowchart of the inclusion criteria for the literature*

The complete search yielded a total of **31 studies**. A flow chart (figure 1) was then used whereby inclusion criteria determined the outcome of the chosen **13 studies**. 3 studies were then excluded because they documented a single outcome. Thus, they wer subject to the exclusion criteria. This resulted in a final **10 studies**, depicted in table 2. These studies and the quality assessment are shown in **Appendix 1 and 2**.

3 – Results

__Table P.2__: Summary of the methods and measurement tools in the chosen articles

Author	Population	Measurement Tools	Intervention	Comparison
[I] Tremblay et al., (1994)	- n = 27 - BMI < 25kgm^2 - No chronic disease	- BFP - biopsy	- **HI** = 10-15 bouts - **LI** = 4-5 bouts - **Time** = 25-30 min - **Frequency** = 3/week - **Duration** = 15 weeks	- **Intensity** = 60-70% HR_{max} - **Time** = 30 min - **Frequency** = 4-5/week - **Duration** = 20 weeks
[II] Eimaries-kandari et al. (2012)	- n = 21 - BMI > 30kgm^2 - Female	- BMI - Gaseous exchange	- **HI** = 4 bouts of 4 min (80-90% VO_2peak) - **LI** = 3 bouts of 3 min (50-60% VO_2peak) - **Time** = 33 min - **Frequency** = 3/week - **Duration** = 8 weeks	- **Intensity** = 50-71% HR_{max} - **Time** = 41 min - **Frequency** = 3/week - **Duration** = 8 weeks
[III] Homaee et al. (2014)	- n = 32 - BMI >25kgm^2 - Male	- BMI - Gaseous exchange	- **HI** = 4-6 bouts of 1 min (85-95% VO_2peak) - **LI** = 4-6 bouts of 1 min (50-55% VO_2peak) - **Time** = 16-36 min - **Frequency** = 3/week - **Duration** = 12 weeks - **Diet also present**	- **Intensity** = 55-70% VO2peak - **Time** = 30-45 min - **Frequency** = 3/week - **Duration** = 12 weeks
[IV] Cheema et al., (2015)	- n = 12 - BMI >30kgm^2	- Abdominal obesity - BMI - Gaseous exchange - Quality of life questionaire	- **HI** = 10-16 bouts of 2 min (boxing) - **LI** = 10-16 bouts of 1 min (pacing) - **Time** = 30-50 min - **Frequency** = 4/week - **Duration** = 12 weeks	- **Intensity** = Brisk Walking - **Time** = 50 min - **Frequency** = 4/week - **Duration** = 12 weeks
[V] Burgomaster et al. (2008)	- n = 20 - Sedentary - Young age - No chronic disease	- biopsy - gaseous exchange - exercise test - telemetry	- **HI** = 4-6 bouts of 30s (90% VO_2peak) - **LI** = 4-6 bouts of 4 min (pacing) - **Time** = 18-26 min - **Frequency** = 3/week - **Duration** = 6 weeks	- **Intensity** = 65% VO_2peak - **Time** = 40-60 min - **Frequency** = 5/week - **Duration** = 6 weeks
[VI] Schjerve et al., (2008)	- n = 40 - BMI > 25kgm^2 - No chronic disease	- FMD - Blood test (fasting) - gaseous exchange - glucose tolerance	- **HI** = 4 bouts of 4 min (85-95% HR_{max}) - **LI** = 3 bouts of 3 min (50-60% HR_{max}) - **Time** = 25 min - **Frequency** = 3/week	- **Intensity** = 60-70% HR_{max} - **Time** = 47 min - **Frequency** = 3/week - **Duration** = 12 weeks

__Table P.2 (continued)__: Summary of the methods and measurement tools in the chosen literature articles

Keating et al. (2014)	- BMI > 25kgm^2 - Sedentary	- SPE - BFP - BMI - BP - Blood test	- **LI** = 2-3 min (low intensity) - **Time** = 20-24 min - **Frequency** = 3/week - **Duration** = 12 weeks	- **Time** = 30-45 min - **Frequency** = 3/week - **Duration** = 12 weeks
[VIII] Nalcakan (2014)	- n = 15 - Male - Recreational athletes	- BMI - BFP - gaseous exchange	- **HI** = 4-6 bouts of 30s (90% VO_2peak) - **LI** = 4-6 bouts of 4.5 min (pacing) - **Time** = 20-29 min - **Frequency** = 3/week - **Duration** = 7 weeks	- **Intensity** = 60% VO_2peak - **Time** = 30-50 min - **Frequency** = 3/week - **Duration** = 7 weeks
[IX] Rakobowchuk et al. (2008)	- n = 20 - No chronic disease	- gaseous exchange	- **HI** = 4 bouts of 4 min (85-95% HR_{max}) - **LI** = 3 bouts of 3 min (50-60% HRmax) - **Time** = 25 min - **Frequency** = 3/week - **Duration** = 6 weeks	- **Intensity** = 65% VO_2peak - **Time** = 40-60 min - **Frequency** = 5/week - **Duration** = 6 weeks
[X] Gibala et al. (2006)	- n = 16 - Male - Recreational athletes	- gaseous exchange - time trials	- **HI** = 4-6 bouts of 30s (250% VO_2peak) - **LI** = 4-6 bouts of 4 min (pacing) - **Time** = 18-26 min - **Frequency** = 3/week - **Duration** = 2 weeks	- **Intensity** = 65% VO_2peak - **Time** = 90-120 min - **Frequency** = 3/week - **Duration** = 2 weeks

3.1 HIIT versus CET in the context of body weight reduction

A BMI reduction range of 25 kgm^2 – 29.9kgm^2 has been commonly associated with an increase in longevity and decrease in morbidity as well as mortality [WHO, 2010]. Initially, Cheema et al. (2015), noted that waist circumference, body mass and BMI were reduced in a HIIT group undertaking boxing with small to medium effect (Cohen's d = 0.29-0.48) with no statistical significance when compared to a CET group. Alternatively, no significant change in body weight in response to either the intervention or the comparison in Trembley et al., (1994) and, Eimarieskandari et al. (2012) after 15-20 weeks and 8 weeks of training, respectively. In the latter study, the HIIT group (n = 7), reportedly began the trial at 77.13 ± 2.7 kg and progressed to 76.87 ± 2.88 kg after 4 weeks and 76.64 ± 2.84 kg after 8 weeks. Conversely, the CET group (n = 7) started the trial at 78.68 ± 5.9 kg and progressed to 77.66 ± 5.87 after 4 weeks and 77.59 ± 6.18 kg after 8 weeks.

Homaee et al., (2014) compared a control (diet), comparison (CET and diet) and intervention (HIIT and diet) in overweight/obese subjects. The diet reduced energy intake by 500 kcal daily in the control group and by 357 kcal daily in the intervention and control group. All diets, however, consisted of macronutrient proportions of 50-55% carbohydrate, 15-25% protein and 25-30% lipid. There resultant weight loss after 12 weeks was:

- Diet only (control); -5.2% bodyweight ($p < 0.001$)
- Diet and CET (comparison); -3.6% bodyweight, ($p <0.001$)
- Diet and HIIT (intervention); -7.9% ($p < 0.001$)

Schjerve et al., (2008) then observed a body weight reduction of 3% ($p < 0.005$) and 2% ($p < 0.05$) with CET and HIIT respectively, concordantly noting a decrease in BMI in both respective groups:

- CET group; went from 36.7 ± 1.4 kgm^2 to 35.6 ± 1.4 kgm^2, $p < 0.007$
- HIIT group; went from 36.6 ± 1.2 kgm^2 to 36.0 ± 1.2 kgm^2, $p < 0.04$

Conversely, Keating et al. (2014) did not find any significant change in HIIT, CET or placebo in weight reduction following 12 weeks of training ($p = 0.30$). However, in Nalcakan (2014), 7 weeks of CET (n = 7) induced a body mass change of -1.1% (i.e. 79.3 ± 6.69 kg to 78.4 ± 6.96 kg, $p = 0.140$, $d = -0.132$) and a body mass change of -0.6% in a HIIT group (86.2 ± 8.00 kg to 85.7 ± 7.42 kg, $p = 0.53$, $d = -0.065$) with both changes not being statistically significant. The resultant change in BMI was also non-significant in either study group.

Lastly, in a 6 week trial by Rakobowchuk et al., (2008), weight was reduced but no information was given regarding significance. However weight in:

- HIIT group; 69.1 ± 9.4 kg (BMI 23.6 ± 3.0 kgm^2) decreased to 68.3 ± 8.9 kg after 6 weeks (BMI 23.3 ± 3.0 kgm^2)
- CET group; 75.4 ± 13.3 kg (BMI 24.3 ± 2.1 kgm^2) decreased to 74.9 ± 12.7 kg (BMI 24.2 ± 2.0 kgm^2) after 6 weeks.

Table P.3: *Summary of the results in relation to weight reduction for HIIT and CET*

Author	Population	HIIT	CET	Outcome (HIIT)	Outcome (CET)
[I] Trembley et al., (1994)	- n = 27 - BMI < 25kgm² - No chronic disease	- **Time** = 25-30 min - **Frequency** = 3/week - **Duration** = 15 weeks	- **Time** = 30 min - **Frequency** = 4-5/week - **Duration** = 20 weeks	- No significant change	- No significant change
[II] Eimarieskandari et al., (2012)	- n = 21 - BMI > 30kgm² - Female	- **Time** = 33 min - **Frequency** = 3/week - **Duration** = 8 weeks	- **Time** = 41 min - **Frequency** = 3/week - **Duration** = 8 weeks	- No significant change	- No significant change
[III] Homaee et al., (2014)	- n = 32 - BMI >25kgm² - Male	- **Time** = 16-36 min - **Frequency** = 3/week - **Duration** = 12 weeks - **Diet also present**	- **Time** = 30-45 min - **Frequency** = 3/week - **Duration** = 12 weeks	- A 7.9% weight reduction ($p < 0.0001$)	- A 3.6% weight reduction ($p < 0.0001$)
[IV] Cheema et al., (2015)	- n = 12 - BMI >30kgm²	- **Time** = 30-50 min - **Frequency** = 4/week - **Duration** = 12 weeks	- **Time** = 50 min - **Frequency** = 4/week - **Duration** = 12 weeks	- A significant change in BFP ($p = 0.047$), waist circumference, weight and BMI ($d = 0.41$)	- No significant change
[V] Schjerve et al., (2008)	- n = 20 - Sedentary - Young age - No chronic disease	- **Time** = 18-26 min - **Frequency** = 3/week - **Duration** = 6 weeks	- **Time** = 40-60 min - **Frequency** = 5/week - **Duration** = 6 weeks	- 2% reduction in bodyweight ($p < 0.05$)	- 3% reduction in bodyweight ($p < 0.005$)
[VII] Keating et al., (2014)	- n = 38 - BMI > 25kgm² - Sedentary	- **Time** = 20-24 min - **Frequency** = 3/week - **Duration** = 12 weeks	- **Time** = 30-45 min - **Frequency** = 3/week - **Duration** = 12 weeks	- No significant change	- No significant change
[VIII] Nalkacan (2014)	- n = 15 - Male - Recreational athletes	- **Time** = 20-29 min - **Frequency** = 3/week - **Duration** = 7 weeks	- **Time** = 30-50 min - **Frequency** = 3/week - **Duration** = 7 weeks	- A 0.6% reduction in body weight (not significant)	- A 1.1% reduction in body weight (not significant)
[IX] Rakobowchuck et al., (2008)	- n = 20 - No chronic disease	- **Time** = 25 min - **Frequency** = 3/week - **Duration** = 6 weeks	- **Time** = 40-60 min - **Frequency** = 5/week - **Duration** = 6 weeks	- Weight reduced but not significant	- Weight reduced but not significant

3.2 HIIT versus CET in the context of body composition

In the first trial (Trembley et al., 1994), both CET (20 weeks) and HIIT (15 weeks) was not enough to cause a significant reduction in bodyweight in obese individuals, the reduction in the sum of six skinfolds was greater in the HIIT group. However, despite the difference in TEE (**57.9 ± 14.4 mJ** in the HIIT and **120.4 ± 31.0 mJ** in the CET group, $p < 0.01$) both training programs included significant reductions in the suprailiac skinfold and sum of the three trunk subcutaneous skinfolds. However, if TEE was adjusted to be the same, the estimated fat loss that would have been nine times greater within the intervention group, ($p < 0.01$). Within the HIIT group, an additional significant decrease in tricep, bicep, subscapular skinfolds and sum of 3 limb skinfolds as well as sum of six skinfolds was also seen.

Despite no changes in bodyweight, Eimarieskandari et al., (2012) documented that 8 weeks of CET and HIIT were enough to elicit a change in body composition. However, a significant decrease in BFP ($p = 0.014$), fat mass ($p = 0.015$) and waist-hip ratio ($p = 0.007$) had only been observed in the comparison (CET) group. BFP reduction was significant in the CET group after just 4 weeks ($p = 0.029$) and in the HIIT group after the complete 8 weeks ($p = 0.011$). Remarkably, after 8 weeks the BFP reduction in the CET group was significantly larger than that of the HIIT group ($p = 0.02$) and the control group ($p = 0.03$).

In a more direct study, Cheema et al. (2015), compared boxing for a HIIT group and brisk walking in a CET group ($n = 12$) and noted that in the intervention group, a reduced BFP ($p = 0.047$, Cohen's $d = 0.41$) was seen. The CET group also reduced BFP over the course of training with small effect (Cohen's $d = 0.21$; $p = 0.17$). Participants in the CET group showed no other effects. Despite a reduction in bodyweight, Schjerve et al., (2008) also noted that BFP decreased by 2.5% (p <

0.03) in the CET and 2.2% ($p < 0.02$) in the HIIT groups, with no changes in the waist/hip ratio. Alternatively, in Keating et al., (2008) noted significant decreases in BFP ($p = 0.049$) and a near-significant reduction in trunk fat ($p = 0.07$) in CET only, with no significant changes in lean body mass and weight in either CET or HIIT. An additional statistical difference favouring CET was also seen in android fat between the comparison and intervention groups ($p = 0.01$)

In Nalcakan (2014), two indicators of body composition change were measured; waist/hip ratio and BFP after 7 weeks of training in either CET or HIIT. The CET group had a significant change ($p = 0.001$, $d = -0.868$) from **82.4 ± 3.94 cm** to **79.2 ± 3.41 cm** (-3.9%) in waist circumference. The HIIT group showed a significant change in waist circumference ($p = 0.023$, $d = -0.393$) with a mean change from **86.8 ± 7.88 cm** to **83.9 ± 6.85 cm** (-3.3%). A significant change in the waist/hip ratio, was only noted in the HIIT group ($p = 0.033$, $d = -0.040$) with a change of -2.4% as opposed to the 1.2% in the CET group. Nalcakan (2014) also noted a statistical change in the BFP in both CET and HIIT groups:

- CET group; **15.8 ± 2.62 %** reduced to **14.9 ± 2.63 %** (-5.7% mean change, $p = 0.015$, $d = -0.343$)
- HIIT group; **16.5 ± 3.72 %** reduced to **15.3 ± 3.15 %** (-7.3% mean change, $p = 0.007$, $d = -0.348$)

Table P.4: *Summary of the results in relation to body composition for HIIT and CET*

Author	Population	HIIT	CET	Outcome (HIIT)	Outcome (CET)
[I] Tremblay et al., (1994)	- n = 27 - BMI < 25kgm^2 - No chronic disease	- **Time** = 25-30 min - **Frequency** = 3/week - **Duration** = 15 weeks	- **Time** = 30 min - **Frequency** = 4-5/week - **Duration** = 20 weeks	- Significant reduction in BFP (up to 9x greater than CET if TEE was corrected)	- Significant ($p < 0.05$) reduction in suprailiac skinfold and sum of three trunk skinfolds
[II] Eimaries-kandari et al. (2012)	- n = 21 - BMI > 30kgm^2 - Female	- **Time** = 33 min - **Frequency** = 3/week - **Duration** = 8 weeks	- **Time** = 41 min - **Frequency** = 3/week - **Duration** = 8 weeks	- Significant change in fat mass after 8 weeks ($p = 0.011$)	- Significant change in fat mass after 4 weeks ($p = 0.029$), - Significant changes in BFP, BFP ($p = 0.014$), fat mass ($p = 0.015$) and waist-hip ratio ($p = 0.007$). - Significant difference between HIIT group ($p = 0.02$)
[IV] Cheema et al., (2015)	- n = 12 - BMI >30kgm^2	- **Time** = 30-50 min - **Frequency** = 4/week - **Duration** = 12 weeks	- **Time** = 50 min - **Frequency** = 4/week - **Duration** = 12 weeks	- Significantly reduced BFP ($p = 0.047$)	- Non-significantly reduced BFP
[VI] Schjerve et al., (2008)	- n = 40 - BMI > 25kgm^2 - No chronic disease	- **Time** = 25 min - **Frequency** = 3/week - **Duration** = 12 weeks	- **Time** = 47 min - **Frequency** = 3/week - **Duration** = 12 weeks	- 73% increase in Ca^{2+} ($p < 0.05$) re-uptake, - 2.2% ($p < 0.02$) decrease in body fat	- 2.5% ($p < 0.03$) decrease in total body fat
[VII] Keating et al. (2014)	- n = 38 - BMI > 25kgm^2 - Sedentary	- **Time** = 20-24 min - **Frequency** = 3/week - **Duration** = 12 weeks	- **Time** = 30-45 min - **Frequency** = 3/week - **Duration** = 12 weeks	- No significant change	- Significant change in total BFP, reduction of android fat ($p = 0.01$)
[VIII] Nalcakan (2014)	- n = 15 - Male - Recreational athletes	- **Time** = 20-29 min - **Frequency** = 3/week - **Duration** = 7 weeks	- **Time** = 30-50 min - **Frequency** = 3/week - **Duration** = 7 weeks	- Significant change in waist circumference ($p = 0.023$) - Significant change in waist/hip ratio ($p = 0.033$, -2.4%) - Significant change in BFP (-7.3%, $p = 0.007$)	- Significant change in waist circumference ($p = 0.001$) - Significant change in BFP (-5.7%, $p = 0.015$)

3.3 HIIT versus CET in the context of fitness

This section of results was concerned with fitness enhancement. In relation to the chosen literature, this section documents results in relation to VO2peak, Blood Markers…

3.3.1 HIIT versus CET in the context of fitness via VO_2max

In Trembley et al. (1994), VO_2max increased in both HIIT and CET groups using gaseous exchange:

- Comparison VO_2max (CET); **36.6 ± 7.9 mL/kg/min** increased to **48.2 ±7.7 mL/kg/min** ($p < 0.01$)
- Intervention VO_2max (HIIT); **38.7 ± 8.8 mL/kg/min** increased to **48.6 ± 7.0 mL/kg/min** ($p < 0.01$)

Schjerve et al., (2008) also noted an increase in VO_2max in relation to strength training, CET and HIIT by 10%, 16% and 33% respectively ($p < 0.001$ for all). The change in VO_2max in CET was not statistically different from strength training. However, changes in comparison to HIIT were all significant.

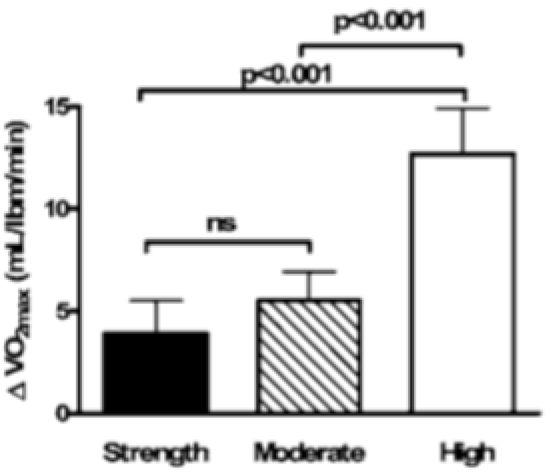

Figure 2: Change in VO_2max in 3 groups after 12 weeks of strength training, moderate-intensity CET and HIIT (Schjarve et al., 2008)

VO_2peak also increased after training with both the intervention and comparison ($p < 0.05$), and no difference was seen between groups (Burgomaster et al., 2008). Alternatively, in Eimarieskandari et al. (2012), 8 weeks of either HIIT or CET was not enough to cause a significant change in VO_2max when compared to a control. Nalcakan (2014) documented further changes in VO_2max following 7 weeks of CET and HIIT. As shown in figure 3, a significant change was noted in the CET group as early as 3 weeks into undertaking CET (whereas the change was not yet significant with HIIT). After 7 weeks, the percentage change in VO_2peak was 8.7% in the CET ($p = 0.014$) and 7.0% in the HIIT ($p = 0.022$) groups.

Influence of CET and SIT on indices of the aerobic power test

	CET (n=7)						SIT (n=8)					
	Week No	M ± SD	Paired Weeks	Δ%	p	d	Week No	M ± SD	Paired Weeks	Δ%	p	d
VO_2max (ml•min-1•kg-1)	W0	40.5 ± 6.0	W3-W0	4.4	0.038*	0.327	W0	40.2 ± 4.3	W3-W0	3.0	0.099	0.292
	W3	42.3 ± 5.0	W7-W3	4.1	0.018*	0.358	W3	41.4 ± 3.9	W7-W3	3.9	0.009*	0.410
	W7	44.0 ± 4.8	W7-W0	8.7	0.014*	0.654	W7	43.0 ± 3.9	W7-W0	7.0	0.022*	0.682

Figure 3: 7 weeks of CET or HIIT (SIT) in Nalcakan (2014)

Rakobowchuk et al. (2008) also reported a change in VO_2peak with HIIT and CET. The change was important considering the TEE in each group:

- HIIT group (**225 kJ/week**, 500 W work intervals); **41± 2 ml.kg^{-1}·min^{-1}** increased to **44± 2 ml.kg^{-1}·min^{-1}**.
- CET group (**2250 kJ/week**, 150 W work intervals); **41± 2 ml.kg^{-1}·min^{-1}** increased to **45 ± 2 ml.kg^{-1}·min^{-1}**.

3.3.2 HIIT versus CET in the context of fitness via enzymatic activity

Trembley et al. (1994) documented a significant increase in **malate dehydrogenase** activity in both HIIT (by 62.6 ± 20.9 U/g, $p < 0.01$) and CET (by 56.6 ± 41.9 U/g, $p < 0.01$) groups. However **hexokinase** (0.31 ± 0.27 U/g, $p < 0.01$), **phosphofructokinase** (20.5 ± 27.7 U/g, $p < 0.05$) and **hydroxyacyl-Coenzyme A dehydrogenase** (2.10 ± 1.29 U/g, $p < 0.01$) activities were only significantly increased in the intervention (HIIT) group. Significant improvements ($p <0.05$) were also shown for mitochondrial enzymes citrate synthase, β-HAD and PDH and the protein PGC-1α (Burgomaster et al., 2008).

Schjerve et al., (2008) documented an increase in PGC-1α protein levels in a HIIT group following 12 weeks of training ($p < 0.01$). This was also seen in a group who undertook strength training but not in those undergoing CET. Furthermore, the maximal rate of calcium ion re-uptake into the sarcoplasmic reticulum was also increased by 73% (HIIT) and 72% (strength training) when compared with CET. These biomarkers were important as PGC-1α is a regulator of mitochondrial biogenesis and thus may contribute to improved fitness.

3.3.3 HIIT versus CET in the context of fitness via clinical parameters

In Cheema et al., (2015) it was noted that the HIIT group had reduced **SBP** ($p < 0.001$), **DBP** ($p < 0.001$), **HR** ($p < 0.001$) and **pulse pressure** ($p = 0.026$) following 12 weeks of boxing. In comparison, the CET group only showed a raised pulse pressure. Schjerve et al., (2008) observed a further decrease in DBP by 9% ($p < 0.002$) in the CET group and a 7% ($p < 0.02$) in the HIIT group. On the other hand, the resting HR, SBP and DBP were not significantly altered after 6 weeks of work in either exercise group in Rakobowchuk et al., (2008). A change HR was confirmed once again by Burgomaster et al., (2008), who, noted a statistical difference within the HIIT (SIT) group (from **160 ± 5 bpm** to **151 ± 6 bpm**) as well as the CET group (from 157 ± 5 to 144 ± 5 bpm) with $p < 0.05$.

3.3.4 HIIT versus CET in the context of fitness via blood and muscle parameters

C-reactive protein (CRP) was also markedly reduced (with a significant difference) in a study by Homaee et al., (2014), who showed that 12 weeks of intervention decreased CRP by 38.2% ($p < 0.001$), and comparison by 29% (p 0.026) and control (via diet) by 25.4% ($p < 0.003$). The difference however, was not significant ($p = 0.261$). Schjerve et al., (2008) also attempted to investigate the impact of 12 weeks of HIIT or CET on CRP levels, however, did not document any notable changes with either exercise. Incidentally, the amount of oxidized LDL decreased significantly after strength training ($p < 0.005$) and CET ($p < 0.04$), but not after HIIT. A similar investigation by Nalcakan (2014) noted no significant differences in HDL, LDL, VLDL or TG alterations following 7 weeks of HIIT or CET.

Muscle PCr content was higher at 60 minutes of exercise post-training ($p < 0.05$) compared to pre-training with no statistical differences between groups, whereas **creatine** showed the opposite change ($p < 0.05$) with no statistical difference noted between HIIT and CET (Burgomaster et al., 2008). The authors also showed that whilst **muscle ATP** remained unchanged by acute exercise, it was reduced after 6 weeks of HIIT (when compared to CET, $p < 0.05$).

3.3.5 HIIT versus CET in the context of fitness via fat and muscle oxidation

Burgomaster et al., (2008) noted changes in **RER** (**0.977 ± 0.01** to **0.965 ± 0.01** in the HIIT group and **0.967 ± 0.01** to **0.941 ± 0.01** in the CET group, $p < 0.05$) and **ventilation** (**48 ± 3 min** $^{-1}$ to **42 ± 3 l min** $^{-1}$ in HIIT group and **47 ± 5 l min** $^{-1}$ to **42 ± 4**

l min $^{-1}$ in CET group, $p < 0.05$). Alternatively, RER changes were not significant from those measured in the pre-test in Schjerve et al., (2008).

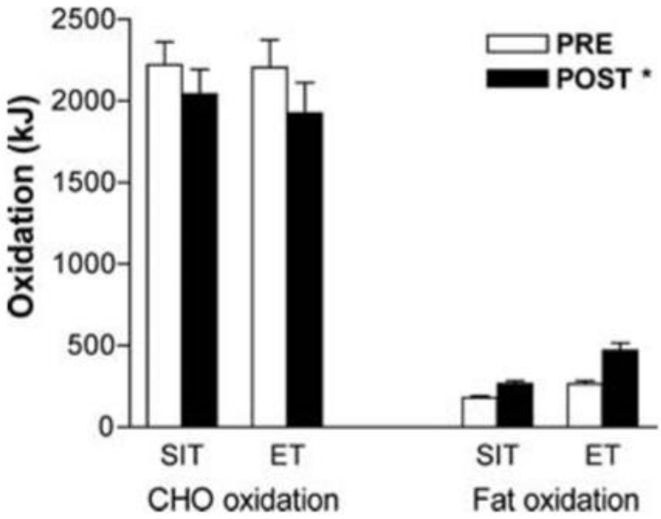

Figure 4: *Changes in carbohydrate and fat oxidation pre- and post- HIIT (SIT) and CET (ET) in Burgomaster et al., (2008)*

Burgomaster et al., (2008) also noted a reduced net muscle glycogenolysis after training in both intervention and comparison groups ($p < 0.05$). Numerically, the decrease was:

- HIIT; **283 ± 28 mmol (kg dry wt)** $^{-1}$ to **166 ± 20 mmol (kg dry wt)** $^{-1}$
- CET; **226 ± 15 mmol (kg dry wt)** $^{-1}$ to **154 ± 25 mmol (kg dry wt)** $^{-1}$

Figure 3 highlights findings by Burgomaster et al., (2008) which suggested that both exercises tended to preserve glycogen stores and promote fat oxidation, independent of exercise ($p > 0.05$), with no real difference between HIIT or CET.
A 2 week trial of supramaximal HIIT versus submaximal CET, Gibala et al. (2006) studied the effects of muscle oxidative capacity, muscle buffering capacity and muscle glycogen content in relation to each exercise. There was no significant change in COX activity between groups, which increased in both groups after training ($p = 0.04$). The muscle buffering capacity also increased after training by

7.6% (HIIT) and 4.2% (CET) with no difference between groups. Lastly, the resting muscle glycogen content increased by 28% (HIIT) and 17% (CET) with no difference between groups.

3.3.6 HIIT versus CET in the context of fitness via performance

Burgomaster et al., (2008) noted a peak power output increase in the HIIT group (by 17%) and in the CET group (7%) with $p < 0.05$ for both (no difference between groups). Gibala et al. (2006) then measured the time required to complete a 750 kJ cycling test in HIIT and CET groups and noted that the cycling test time decreased by 10.1% in the HIIT group and by 7.5% in the CET groups ($p < 0.001$) with no significant difference between the groups.

3.4 Adherence to training within HIIT and CET groups

The dropout rate between the HIIT and CET groups were not statistically different in Trembley et al., (1994). 1 adverse effect (tennis elbow) occurred in Cheema et al. (2015) within the HIIT (boxing) group. However, the participant continued the trial via use of kicks in place of punches. Adherence within this study was notably better in the boxing group (79 ±15%) rather than the brisk walk/CET group (55 ± 43%). However, the difference in attendance was not statistically significant between groups. In Keating et al., (2014), 33 of the 38 enrolled participants completed the training and each of the placebo, however the attrition rate was 85% for both the HIIT group as well as the CET group. Lastly, in Nalcakan (2014), 3 of the 15 participants withdrew from the study due to health problems. However, it was not stipulated as to which group (HIIT or CET) caused them.

***Table P.5**: Summary of the results in relation to fitness in HIIT and CET*

Author	Population	HIIT	CET	Outcome (HIIT)	Outcome (CET)
[I] Tremblay et al., (1994)	- n = 27 - BMI < 25kgm^2 - No chronic disease	- **Time** = 25-30 min - **Frequency** = 3/week - **Duration** = 15 weeks	- **Time** = 30 min - **Frequency** = 4-5/week - **Duration** = 20 weeks	- sig. increase in VO_2peak ($p=0.01$) - sig. increase in MDH, HK, PFK, and HADH ($p<0.05$)	- sig. increase in VO_2peak ($p=0.01$) - sig. increase in MDH
[III] Homaee et al. (2014)	- n = 32 - BMI >25kgm^2 - Male	- **Time** = 16-36 min - **Frequency** = 3/week - **Duration** = 12 weeks - **Diet also present**	- **Time** = 30-45 min - **Frequency** = 3/week - **Duration** = 12 weeks	- sig. reduction in CRP (38.2%, $p <0.001$)	- sig. reduction in CRP (29%, $p <0.026$) - sig. reduction in oxidized LDL ($p <0.04$)
[IV] Cheema et al., (2015)	- n = 12 - BMI >30kgm^2	- **Time** = 30-50 min - **Frequency** = 4/week - **Duration** = 12 weeks	- **Time** = 50 min - **Frequency** = 4/week - **Duration** = 12 weeks	- sig. reduction in SBP, DBP, HR and pulse pressure ($p>0.05$)	- slight rise in pulse pressure
[V] Burgomaster et al. (2008)	- n = 20 - Sedentary - Young age - No chronic disease	- **Time** = 18-26 min - **Frequency** = 3/week - **Duration** = 6 weeks	- **Time** = 40-60 min - **Frequency** = 5/week - **Duration** = 6 weeks	- sig. increase in VO_2peak ($p=0.05$) - sig. decrease in HR ($p<0.05$) - sig. reduction in RER ($p<0.05$) - sig. reduction in ventilation ($p<0.05$) - sig. reduction in glycogenolysis ($p<0.05$) - sig. increase in peak power (17%)	- sig. increase in VO_2peak ($p=0.05$) - sig. decrease in HR ($p<0.05$) - sig. reduction in ventilation ($p<0.05$) - sig. reduction in glycogenolysis ($p<0.05$) - sig. increase in peak power (7%)
[VI] Schjerve et al., (2008)	- n = 40 - BMI > 25kgm^2 - No chronic disease	- **Time** = 25 min - **Frequency** = 3/week - **Duration** = 12 weeks	- **Time** = 47 min - **Frequency** = 3/week - **Duration** = 12 weeks	- sig. increase in VO_2peak (33%, $p=0.001$) - sig. increase in PGC-1α ($p=0.01$) - sig. increase in Ca^{2+} re-uptake (73%) - sig decrease in DBP (7%, $p= 0.02$)	- sig. increase in VO_2peak (16%, $p=0.001$) - decrease in DBP (9%, $p<0.002$)
[VIII] Nalcakan (2014)	- n = 15 - Male - Recreational athletes	- **Time** = 20-29 min - **Frequency** = 3/week - **Duration** = 7 weeks	- **Time** = 30-50 min - **Frequency** = 3/week - **Duration** = 7 weeks	- sig. increase in VO_2peak (7%, $p=0.022$)	- sig. increase in VO_2peak (8.7%, $p=0.014$)

Table P.5 (continued): *Summary of the results in relation to fitness in HIIT and CET*

[IX] Rakobowchuk et al. (2008)	- n = 20 - No chronic disease	- **Time** = 25 min - **Frequency** = 3/week - **Duration** = 6 weeks	- **Time** = 40-60 min - **Frequency** = 5/week - **Duration** = 6 weeks	- increase in VO2peak with 225kJ/week TEE	- increase in VO2peak with 2250kJ/week TEE
[X] Gibala et al. (2006)	- n = 16 - Male - Recreational athletes	- **Time** = 18-26 min - **Frequency** = 3/week - **Duration** = 2 weeks	- **Time** = 90-120 min - **Frequency** = 3/week - **Duration** = 2 weeks	- Sig. increase in COX activity ($p < 0.05$) - sig. increase in muscle buffering capacity (7.6%) - sig. decrease in time trial (10.1%)	- Sig. increase in COX activity ($p < 0.05$) - sig. increase in muscle buffering capacity (4.2%) - sig. decrease in time trial (7.5%)

4 – Discussion

Within the context of weight reduction, both Trembley et al. (1994) and Eimarieskandari et al. (2012) showed no significant changes in weight after either intervention or comparison training. Following this, Homaee et al. (2014) did show a significant change in body mass following HIIT or CET. However, both intervention and comparison groups were controlled with a standardized diet that left subjects in an energy deficit. The absence of an energy surplus might have enhanced the effect of HIIT in this regard because it may potentially utilize aerobic and anaerobic pathways. Thus, in comparison to CET, which utilizes it may further potentiate the oxidation of fat among other internal sources of energy. This could explain why there was a 7.9% reduction in the HIIT group and 3.6% in the CET group. The same effect was seen in Cheema et al. (2015) in a study that used boxing as a form of HIIT. The interest subjects might have had in boxing might have created a further compliance to training, which in turn would promote the effect of the intervention. The significant weight reduction in Schjerve et al. (2008) noted after just 6 weeks of each exercise (either group) showed how in half the training-time, HIIT was able to achieve a similar end-point (although the reduction in CET was slightly greater). These findings were supported by Nalkacan (2014) who noted a slightly greater response to CET with weight loss. Considering the variations in each exercise protocol, the findings were indicative of the need to create an energy deficit whilst undergoing training. The undertaking of “all-out” exercise was also deemed important in this regard to potentially stimulate excess fat and protein oxidation. However, it did seem that unless diet was controlled for, CET was more efficacious in terms of weight loss. Trembley et al. (1994) suggested that HIIT was more beneficial than CET in achieving a lean body mass. This was especially so when TEE was adjusted to be the same for both. A significant reduction in BFP was seen in HIIT in Cheema et al. (2015) in contrast to that of CET. The additional enjoyment of the exercise however may have psychologically aided the subjects in maximizing the training protocol. Conversely, Eimarieskandari et al. (2012) and Keating et al. (2014) supported the use of CET in the achievement of lean body mass with total effects deemed statistically different from that of the HIIT group in the former. Otherwise, similar changes were noted in Schjerve et al. (2008) and Nalkacan (2014). Once again, diet was deemed an important co-founder in this research, and if research were available using standardized diets, particularly ones with high protein content, the effect of HIIT would be maximized due to the metabolic pathways used in oxidation. However, current research within this study notes that there is no significant differences between the two studies. This premise suggests that HIIT may be a more time-friendly approach to achieve a leaner body composition. However, it was not deemed more efficacious in this regard.

All studies investigating VO_2peak found significant increases in both forms of exercise. Usually, this difference was achieved with less energy expenditure as seen in Rakobowchuk et al. (2008) which compared 225kJ/week (HIIT) with 2250kJ/week (CET). Homaee et al. (2014) otherwise noted a reduced CRP which was with greater effect in the HIIT group. Cardiovascular benefits were also greater in Cheema et al. (2015) noting significantly improved SBP, DBP and HR compared to that of CET. The same effects were noted in Burgomaster et al. (2008) in addition with reduced RER, ventilation, glycogenolysis and an increase in peak power, all seemingly greater than that shown in CET. The decrease in RER theoretically suggested a larger proportion of fat oxidation. In turn, this would promote leaner body compositions in training. The reduced glycogenolysis also supports this claim in that glycogen was actually being preserved within the HIIT groups.

Lastly, studies by Schjerve et al. (2008), Gibala et al. (2006) and Tremblay et al. (1994) all showed the increased efficacy of HIIT in increasing MDH, HK, PFK and HADH, among other physiological components such as PGC-1α, Ca^{2+} reuptake, COX and muscle buffering capacity when compared to CET.

HIIT was deemed more efficacious in light of the research orientated around fitness enhancement due to these findings. This was probably attributed to the high-intensity nature of the activity, which allowed the body to adapt to greater situations of metabolic stress when compared with submaximal activity (CET).

5 - Conclusion

The research provided mixed results in terms of the chosen outcomes. In conclusion, it is possibly best to provide training integrating both forms of training. Ideally, in conjunction with a diet providing a definite energy deficit. It could be the case that performing more frequent bouts of HIIT in comparison with CET may be beneficial due to the increased likelihood that the individual will improve his/her fitness. The improved fitness would allow participants to undergo CET for longer periods of time and in doing so, utilize the full health benefit of prolonged endurance.

Further research is needed to support the findings of this study. Ideally, the dietary component of the trial would be regulated. In addition, more inclusion/exclusion criteria for the study populations can also be used to compare effects of HIIT/CET on groups with different health statuses (such as those of high-BMI or those with established CVD).

Appendix 1: Application of Downs and Black (1998)

	Downs and Black (1998) Question	I	II	III	IV	V	VI	VII	VIII	IX	X
1	Clear hypothesis, aims and objectives	1	1	1	1	1	1	1	1	1	1
2	Clear main outcomes	1	1	1	1	1	1	1	1	1	1
3	Clear patient characteristics	1	1	1	1	1	1	1	1	1	1
4	Clear interventions	1	1	1	1	1	1	1	1	1	1
5	Clear mention of confounders	1	1	1	1	1	1	1	1	1	1
6	Clear main findings	1	2	1	2	2	2	2	2	2	2
7	Estimates of the random variability in the data	2	2	2	2	2	1	1	2	2	1
8	Reports of adverse events	1	1	2	2	2	2	2	2	2	1
9	Patient characteristics lost to follow up	2	2	2	2	1	2	1	2	2	2
10	Clear p values for main outcomes	1	2	2	2	2	2	2	2	2	2
11	Representative population asked	1	1	1	1	1	0	1	0	1	1
12	Representative population prepared to take part	1	0	1	1	1	1	1	1	1	1
13	Interventions representative of real treatment	1	1	1	1	1	2	1	1	1	1
14	Attempts made for blinding subjects	0	0	0	0	0	0	0	0	0	0
15	Attempts made for blinding investigators	0	1	1	1	1	1	1	1	1	1
16	Results based on data dredging	1	1	1	1	1	1	1	1	1	
17	Adjusted analyses for different lengths of follow up	1	1	1	1	1	1	1	1	1	1
18	Appropriate statistical tests	0	1	1	1	1	1	1	1	1	1
19	Compliance to intervention	1	1	1	1	1	1	1	0	1	1
20	Valid and reliable outcome measures	1	1	1	1	1	0	1	1	1	1
21	Were there patients in different intervention groups	1	1	1	1	1	1	1	1	1	1
22	Study subjects in different intervention groups	0	0	1	0	1	1	1	1	1	1
23	Study subjects randomized to intervention groups	1	1	0	1	1	1	0	1	1	1
24	Randomized assignment of groups concealed?	0	1	1	1	1	1	1	1	1	1
25	Adequate adjustment for confounding variables	1	1	1	1	1	1	0	1	1	1
26	Losses of patients to follow up	0	1	1	1	1	1	1	1	1	1
27	Sufficient power present to detect a clinically important effect	4	5	4	4	3	4	4	3	4	5
T	Total	26	32	32	33	32	32	30	30	34	33

Refer to Appendix 2 to see the authors of the chosen articles in relation to the above table.

Appendix 2: The chosen Articles

- [I] **Tremblay, Simoneau and Bouchard (1994)**, Canada
- [II] **Eimarieskandari, Zilaeibouri, Zilaeibouri and Ahangarpour (2012)**, Iran
- [III] **Homaee, Moradi, Azarbayjani and Peeri (2014)**, Iran
- [IV] **Cheema, Davies, Stewart, Papalia and Atlantis (2015)**, Australia
- [V] **Burgomaster, Howarth, Philips, Rakobowchuk, Macdonald, McGee and Giballa (2008)**, Australia
- [VI] **Schjerve, Tyldum, Tjonna, Stolen, Loennechen, Hansen, Haram, Heinrich, Bye, Najjar, Smith, Slordahl, Kemi and Wisloff (2008)**, Norway
- [VII] **Keating, Machan, O'Connor, Gerofi, Sainsbury, Caterson and Johnson, (2014)**, Australia
- [VIII] **Nalcakan, (2014)**, Turkey
- [IX] **Rakobowchuk, Tanguay, Burgomaster, Howarth, GIbala and MacDonald (2008),** Canada
- [X] **Gibala, Little, van Essen, Wilkin, Burgomaster, Safdar, Raha and Tarnopolsky (2006)**, Canada

Appendix 3: The Downs and Black (1998) Questionnaire

1. IS the hypothesis/aim/objective of the study clearly described? Must be explicit Yes/No
2. Are the main outcomes to be measured clearly described in the Introduction or Methods section? If the main outcomes are first mentioned in the Results section, the question should be answered no. ALL primary outcomes should be described for YES
3. Are the characteristics of the patients included in the study clearly described? In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given. Single case studies must state source of patient
4. Are the interventions of interest clearly described? Treatments and placebo (where relevant) that are to be compared should be clearly described.
5. Are the distributions of principal confounders in each group of subjects to be compared clearly described? A list of principal confounders is provided. YES = age, severity
6. Are the main findings of the study clearly described? Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions.
7. Does the study provide estimates of the random variability in the data for the main outcomes? In non-normally distributed data the inter-quartile range of

results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported

8. Have all important adverse events that may be a consequence of the intervention been reported? This should be answered yes if the study demonstrates that there was a comprehensive attempt to measure adverse events (COMPLICATIONS BUT NOT AN INCREASE IN PAIN).
9. Have the characteristics of patients lost to follow-up been described? If not explicit = NO. RETROSPECTIVE – if not described = UTD; if not explicit re: numbers agreeing to participate = NO. Needs to be >85%
10. Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?
11. Were the subjects asked to participate in the study representative of the entire population from which they were recruited? The study must identify the source population for patients and describe how the patients were selected.
12. Were those subjects who were prepared to participate representative of the entire population from which they were recruited? The proportion of those asked who agreed should be stated.
13. Were the staff, places, and facilities where the patients were treated, representative of the treatment the majority of patients receive? For the question to be answered yes the study should demonstrate that the intervention was representative of that in use in the source population. Must state type of hospital and country for YES.
14. Was an attempt made to blind study subjects to the intervention they have received? For studies where the patients would have no way of knowing

which intervention they received, this should be answered yes. Retrospective, single group = NO; UTD if > 1 group and blinding not explicitly stated

15. Was an attempt made to blind those measuring the main outcomes of the intervention? Must be explicit Yes/No/UTD
16. If any of the results of the study were based on "data dredging", was this made clear? Any analyses that had not been planned at the outset of the study should be clearly indicated. Retrospective = NO. Prospective = YES
17. In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case control Studies, is the time period between the intervention and outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should yes. Studies where differences in follow-up are ignored should be answered no. Acceptable range 1 yr follow up = 1 month each way; 2 years follow up = 2 months; 3 years follow up = 3months........10years follow up = 10 months
18. Were the statistical tests used to assess the main outcomes appropriate? The statistical techniques used must be appropriate to the data. If no tests done, but would have been appropriate to do = NO
19. Was compliance with the intervention/s reliable? Where there was non compliance with the allocated treatment or where there was contamination of one group, the question should be answered no. Surgical studies will be YES unless procedure not completed.
20. Were the main outcome measures used accurate (valid and reliable)? Where outcome measures are clearly Yes/No/UTD described, which refer to other work or that demonstrates the outcome measures are accurate = YES. ALL primary outcomes valid and reliable for YES

21. Were the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited from the same population? Patients for all comparison groups should be selected from the same hospital. The question should be answered UTD for cohort and case control studies where there is no information concerning the source of patients
22. Were study subjects in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited over the same time? For a study which does not specify the time period over which patients were recruited, the question should be answered as UTD. Surgical studies must be <10 years for YES, if >10 years then NO
23. Were study subjects randomised to intervention groups? Studies which state that subjects were randomised should be answered yes except where method of randomisation would not ensure random allocation.
24. Was the randomised intervention assignment concealed from both patients and health care staff until recruitment was complete and irrevocable? All non-randomised studies should be answered no. If assignment was concealed from patients but not from staff, it should be answered no.
25. Was there adequate adjustment for confounding in the analyses from which the main findings were drawn? In nonrandomised studies if the effect of the main confounders was not investigated or no adjustment was made in the final analyses the question should be answered as no. If no significant difference between groups shown then YES.
26. Were losses of patients to follow-up taken into account? If the numbers of patients lost to follow-up are not reported = unable to determine.

27. Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance <5% Sample sizes have been calculated to detect a difference of x% and y%.

References

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